X-Band Traveling Wave Resonator (TWR)

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This article covers the design philosophy and operation for an X-band traveling wave resonator (TWR). This equipment will be used to test high-power components for X-band planetary radar.

I. Introduction

It is required that the personnel of the Development Support Group, Section 335, design and build a traveling wave resonator (TWR) to test low-loss components at power levels up to +90 dBm (1×10^6 W) at 8495 MHz $\pm$50 MHz.

II. Background

There have been several TWRs for high-power CW testing (Refs. 1 and 2). The Development Support Group has built and operated a TWR (Ref. 3) to power levels up to +87 dBm (5×10^5 W). One of the main problems with high-power TWR testing is removing the heat dissipated in the waveguide. When a TWR is operating properly, all input power is dissipated in the resonant structure.

III. Theory of Operation

For a lossy TWR structure with no discontinuities, the power multiplication is given by the following formula:

$$M = \left[\frac{C}{1 - T(1 - C^2)^{1/2}}\right]^2 \qquad (1)$$

where

M = power multiplication factor

C = voltage coupling coefficient of directional coupler

T = voltage transmission coefficient of TWR = $10^{-A/20}$ where A = one-way resonator loss in decibels

Setting $dM/dc = 0$ for a constant T to give coupling coefficiency for optimum gain when T is fixed, we have:

$$C_{opt} = (1 - T^2)^{1/2} \qquad (2)$$

Equation (1) is plotted for various values in Fig. 1.

IV. Practical Considerations

It is expected that a TWR for 8495 $\pm$50 MHz will have a total length of approximately 2.5 m with a loss of approximately 0.06 dB/m or a total loss of 0.15 dB. The losses of components to be tested are expected to vary between 0.01 and 0.06 dB. Therefore, the TWR system will have a minimum loss of 0.16 dB and a maximum loss of 0.21 dB.

Solving Eq. (2) for its value, we determine:

$$0.19018 < C_{\text{opt}} < 0.21726$$

The power gain at these coupling coefficients corresponds to:

$$M_{\text{opt}} = \frac{1}{C_{\text{opt}}^2}$$

This corresponds to a power gain of approximately 21 to 27. Since we desire a power gain of greater than 20, the optimum coupling for this requires a C of 0.2236 (13.0 dB). By using a coupler of this value, a maximum of 0.13 dB attenuation in the ring could be tolerated. By referring to Fig. 1, an optimum value for this application (maximum loss for a specified power gain) would be 15 dB. This would allow the resonator gain to be greater than 20 for all values of attenuation greater than approximately 0.16 dB. Figure 2 presents a practical traveling wave resonator.

V. RF Drive

For initial testing of the X-band TWR, it is planned to use the old 20-kW X-band klystron from the R&D clock sync project. With the anticipated TWR parameters, this klystron will allow circulating powers of up to 500 kW. Use of this klystron in connection with the klystron power supplies and support equipment located at the old Microwave Test Facility will avoid committing a high-power X-band klystron (250 kW) and its associated power supply to TWR development. Also, use of this low-power klystron will eliminate the use of warranty time on a new klystron during the relatively long time required to develop and test the TWR.

When it becomes necessary to develop higher power in the TWR than can be generated using the 20-kW klystron, the TWR can be used with the 250-kW klystron. Also, the microwave components used in the TWR are being designed to operate from 7.0 to 8.5 GHz in order to support future development of an X-band DSN uplink, so it would be possible to use the 150-kW clock sync transmitter as a source of RF drive for the TWR.

VI. Mechanical Construction

The main directional coupler should be of similar construction to the one used in the 500-kW TWR (described in Ref. 3), a multihole sidewall coupler 0.9 m (3 ft) long or less. However, hard solder should be used in all joints, and coolant lines would have to be installed on all arms. The main resonator should be constructed of 3.175 mm (0.125 in.) wall WR-125 oxygen-free high conductivity (OFHC) copper guide with standard thick JPL CPR-type flanges. The input and output tuners will be similar to the ones used in the 500-kW S-band TWR with water cooling added.

VII. Cooling

At 500 kW CW, WR-125 OFHC waveguide will have dissipative losses of approximately 7 kW per meter. Also, a properly adjusted TWR will dissipate all of its input power in the resonant structure. Therefore, the cooling should be adequate to remove all of the incident RF energy as heat. Cooling lines will be hard-soldered to the waveguide, and a special coolant manifold will be used to assure adequate coolant flow.

References

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3. Kolbly, R. B., "High-Power Continuous Wave (CW) S-band Traveling Wave Resonator," in *The Deep Space Network*, Space Programs Summary 37-40, Vol. III, pp. 24–26, Jet Propulsion Laboratory, Pasadena, Calif., July 31, 1966.

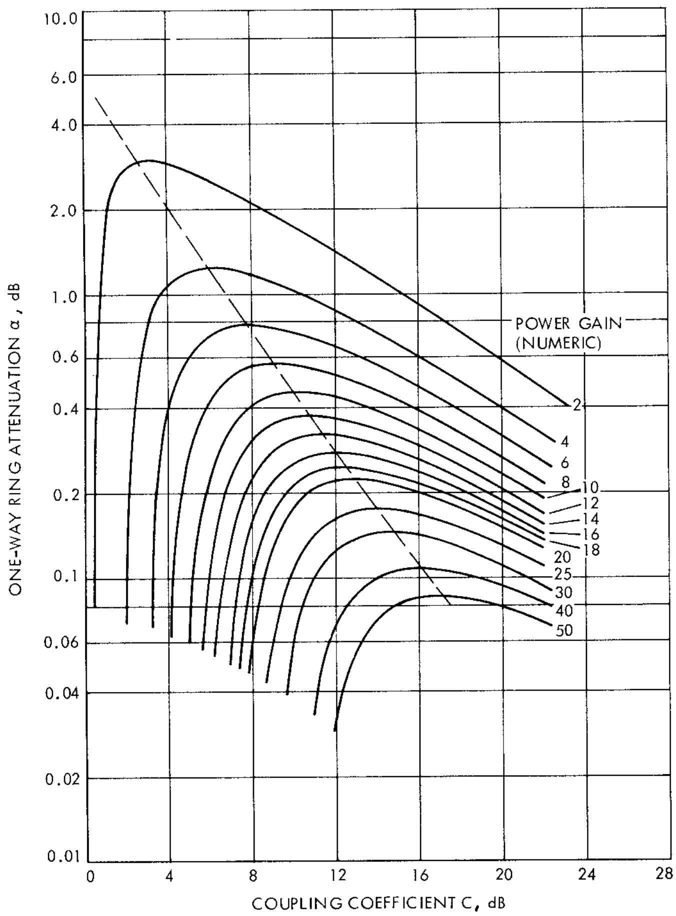

Fig. 1. Traveling-wave resonator characteristics

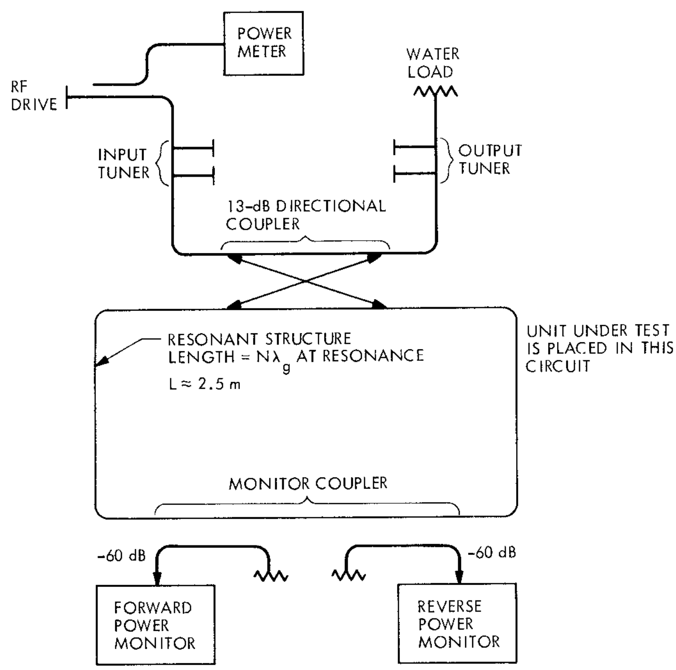

Fig. 2. Block diagram of traveling-wave resonator